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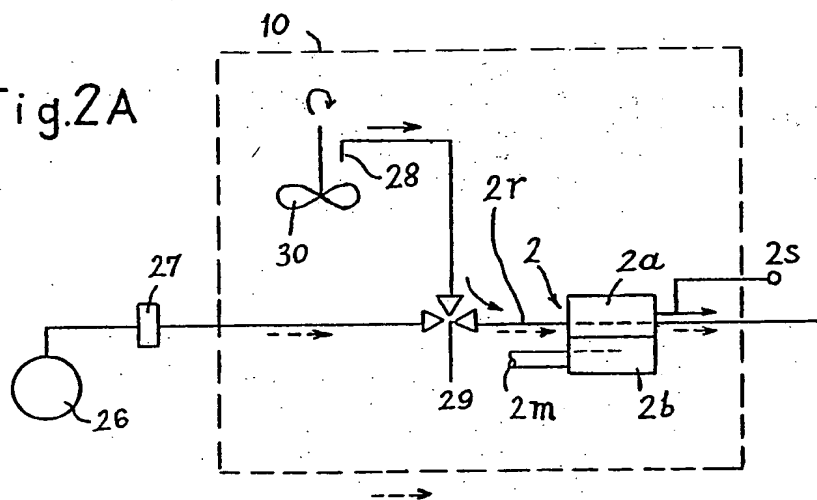
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G1N

(54) Method to zero-set a gas sensor in
a gas-fed incubator

(57) To calibrate or set the zero point and eliminate drift from a CO₂ sensor 2 exposed to an atmosphere in a chamber 10, for cultivation of biological cells, tissues, or of microorganisms, the sensor includes a reference portion 2a and a measuring portion 2b, and, during a calibrating phase valve 29 causes the reference portion to be exposed via 28 to the same gas which is within the chamber 10, and which is to be measured. The resulting output signal should be zero; if, however, due to drift or other changes in the zero-set of the sensor 2, it is not zero, the resulting output signal is stored and then algebraically added to the output signal derived from the sensor when the reference portion is again exposed to a reference gas of known composition, for example air from 26. The correction signal is subtracted from the signal sensed when the reference portion 2a is exposed to the reference gas, and only the measuring portion 2b is exposed to the gas to be measured, within the chamber.

Fig.2A



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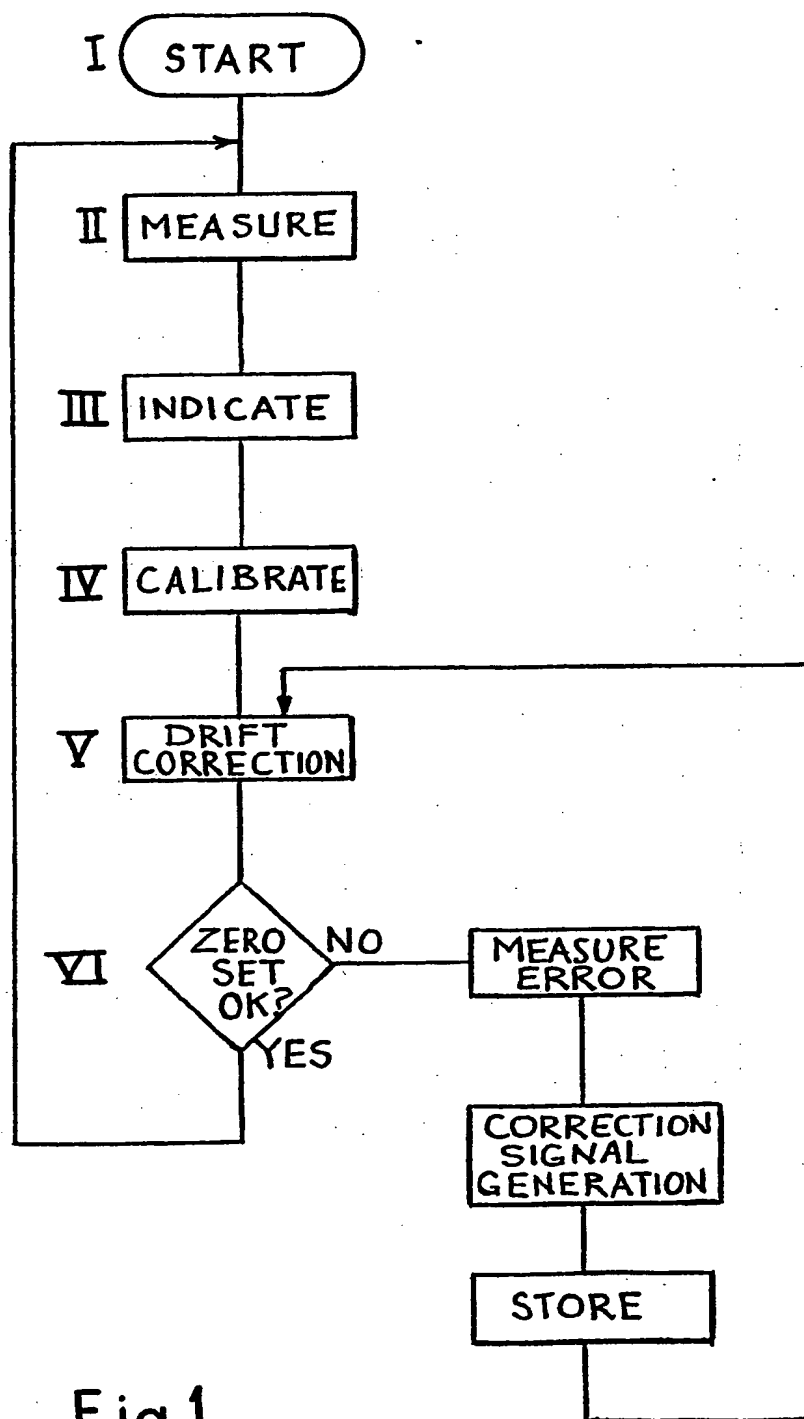


Fig.1

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Fig. 2A

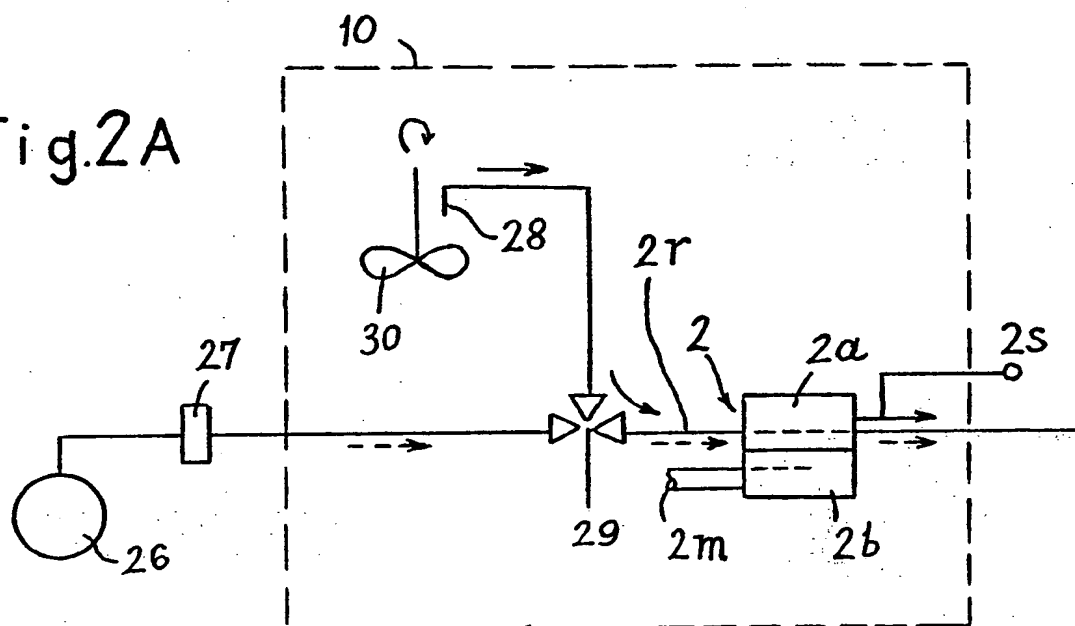
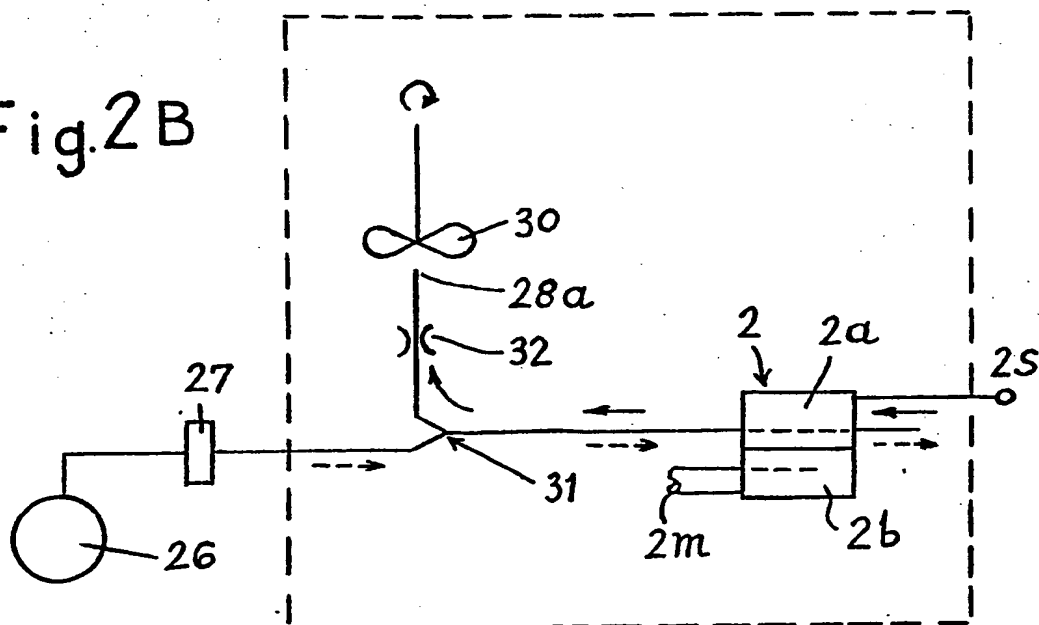


Fig. 2B



SPECIFICATION

Method to zero-set a gas sensor in a gas-fed incubator

5 The present invention relates to monitoring and, if necessary, adjusting the zero-set point of a gas sensor in an incubator or other chamber which is subjected to a predetermined controlled atmosphere, and more particularly to compensate for drift, or change in the zero-set point of a thermal conductivity type carbon dioxide (CO₂) sensor used to control carbon dioxide admission to a treatment chamber especially adapted for treatment of biological substances, particularly for the cultivation of biological cells and tissues, or of microorganisms. The present invention is especially adapted to control and, if necessary readjust, the output signal from such a sensor used in the apparatus disclosed in DE-PS 29 24 446 or US-PS 4 336 329, although it is not of course limited to such an arrangement.

The treatment apparatus of the aforementioned patents includes a sterile treatment chamber and a bypass duct. The bypass duct has various types of sensors located therein, such as temperature, humidity and CO₂ sensors. It has been found necessary to correct output signals from the sensors, and particularly from a CO₂ sensor, from time to time, to be sure that the sensor has not drifted and provided output signals which are not truly representative of the CO₂ concentration. The signal can readily be modified upon detection of drift, to compensate therefor.

It is an object of the present invention to provide a simple method for automatic compensation of possible changes in the zero-setting of a sensor which senses the atmosphere in a chamber, for example of the chamber described in the aforementioned patents, and to eliminate the influence of any drift or change in zero-setting thereof particularly on a measured CO₂ signal.

Briefly, CO₂ sensors of the type to which the invention relates have a measuring section of measuring portion exposed to the gas to be sensed, and a reference portion exposed to a reference gas, for example ambient air. In accordance with the invention, the reference section is connected, from time to time, to the atmosphere prevailing within the treatment chamber, so that, then, the atmosphere applied to both the reference portion as well as to the measuring portion will be the same. The output signal from the sensor, then, should be zero, or null. If it is not, a drift is indicated and the then pertaining output signal is stored and applied as a correction signal when, subsequently, the reference portion is again connected to the reference gas, thereby compensating for any drift, or null or zero-set error of the sensor.

The method has the advantage that it is particularly simple to carry out and effectively eliminates problems of drift of CO₂ measuring cells or sensors. The requirement for periodic checking of the sensor itself for zero or null-setting is eliminated; the drift compensation sensing step is carried out at the actual working temperature of the sensor. The

method can also be used upon replacement, for example, of a sensor element by another one, which might have somewhat different zero-set characteristics, without recalibrating all the electrical and electronic signal processing apparatus used in combination with or in connection with a treatment chamber such as disclosed in the aforementioned patents DE-PS 29 24 446 and US-PS 4 336 329.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a schematic flow diagram of the steps carried out in accordance with the method of the present invention;

Figure 2A is a schematic system diagram, in which all elements and features not necessary for an understanding of the present invention have been omitted; and

Figure 2B is a diagram similar to *Figure 2A*, and showing another embodiment.

To measure the CO₂ content in a treatment chamber as described in the aforementioned patents, the first step is to initiate a start operation, starting the treatment chamber and the various measuring cells. The measuring cells, see *Figures 2A* and *2B* (collectively), use sensors 2, which include a reference portion 2a and a measuring portion 2b. The measuring portion 2b is exposed to the atmosphere through an inlet duct 2m which receives gas circulating in a chamber 10, or in a bypass thereof, as explained in the aforementioned patents.

After starting - see *Figure 1*, step I - the CO₂ concentration is measured, step II. The measured output, derived from an output terminal 2s - see *Figure 2*, collectively - can also be indicated or used to control admission of CO₂, see step III of *Figure 1*.

From time to time, for example under control of a timing or sequencing network, or sometime after initiation of the start command, step I, a calibration subroutine is entered. The calibration subroutine also provides for drift correction. If desired, the steps of measuring, indicating and/or controlling and calibrating can be carried out alternately, sequentially.

The calibrating subroutine, step IV, includes a drift correction step V, and, thereafter, an interrogation step whether the drift correction corresponds or has been properly carried out with respect to a measured condition. In other words, whether, at the time the drift correction is carried out, the output from the sensor is zero, or is not zero. If the zero-set is in order - step VI, "zero-set OK?", the sequence will revert to the measuring step, II, as shown in *Figure 1*. If there is an error, however, an error measurement and correction subroutine is initiated, as seen in *Figure 1*. The error, which has been detected and measured, is used to provide or generate a correction signal, by suitable signal processing, for example in its simplest form merely by amplification, and the signal is then stored in a suitable memory, constructed to store the correction signal. The storage signal is then applied at the next drift correction sequence, step V. This, then, will result in an output at step VI, as controlled by a clock, in "zero-set is OK" signal, so that the output after step VI is "yes", thus reinitiating

the measuring routine.

The entire sequence can be easily controlled by any suitable and well known microcomputer or microprocessor, which steps sequentially and controls sequential processes.

The system is illustrated in Figures 2A and 2B, collectively, to which reference will now be made. An air pump 26 pumps air through a filter 27, for example a sterile filter, to a transfer valve 29 which, for example and preferably, is electromagnetically operated. Rather than using an electromagnetically operated transfer valve 29 (Figure 2A) a Y-junction 31 (Figure 2B) may be used. The following convention is used in the Figures: The solid arrows indicate flow of gases during the calibrating phase. The broken arrows illustrate gas flow during the measuring phase.

In the measuring phase, air is pumped by pump 26 through the sterile filter and the magnetic valve 29 (or the Y-coupling 31, Figure 2B) to the CO₂ detector 2. The measuring portion 2b of the sensor or detector cell 2 is continuously coupled to the atmosphere of the gas within the chamber 10 through the inlet 2m. The chamber 10 has a circulating fan or ventilator 30 therein, which is provided to thoroughly mix the gases applied to the chamber which, for example, and as described in the aforementioned patents, will include steam and vapour, CO₂, and may additionally include other gases, such as nitrogen, oxygen and the like.

In the measuring mode, the cell 2, in accordance with well-known CO₂ sensor or cell construction, carries out a comparison between the gas in the measuring portion 2b and the gas in the reference portion 2a. The gas in the measuring portion is air, see broken-line arrow. The air is passed through the reference portion inlet 2r. An output signal is available at terminal 2s.

During the calibrating mode, the valve 29 switches over to interrupt input from the air pump 26 and, instead, circulates gas within the chamber 10 from an inlet 28 through the reference inlet 2r. At that time, since the gases in the measuring portion and in the reference portion are the same, the output at terminal 2s should be zero. If it is not, a correction signal is generated, stored, and then used to correct the signal in subsequent measuring phases, by algebraic addition of the correction signal, e.g. by subtraction.

Rather than positively feeding gas from the chamber 10 through the reference portion, as shown in Figure 2A, it is also possible to reverse the flow of gases through the reference portion during the calibrating mode, as seen in Figure 2B. The inlet 28a of the duct which is exposed to the atmosphere within the chamber 10 is so positioned with respect to the ventilator or fan 30 that suction is applied thereto. Thus, a portion of the gas atmosphere within the chamber will be supplied, in counter flow, to the reference portion 2a of the sensor through the Y-coupling 31 and through a capillary throttle 32. Flow of air from the air pump 26 is preferably interrupted at that time. Output signals derived from terminal 2s, again, will be stored for algebraic addition to correct signals at subsequent measuring

phases.

CLAIMS

1. Method of compensating for drift or setting of the zero point of a sensor exposed to a controlled atmosphere in a chamber, in which the sensor has a measuring portion and a reference portion, and provides output signals at an output terminal representative of the difference of composition of a gas applied to the measuring portion and a reference gas applied to the reference portion, comprising the steps of
 - exposing the reference portion to the controlled atmosphere within said chamber during a calibrating phase;
 - measuring and storing the resultant output signals during the calibrating phase;
 - and algebraically adding the resulting output signal to the measuring signal when the reference portion is, in a subsequent measuring cycle, exposed to a reference gas.
2. Method according to claim 1, wherein the sensor is a carbon dioxide sensor and wherein the calibrating phase is carried out during interruption of continuously measuring the carbon dioxide content in the atmosphere of the chamber.
3. Method according to claim 1 or 2, wherein the gas flow through the reference portion, in the measuring phase, is in a first predetermined direction; and, during the calibrating phase, gas flow through the reference portion is conducted in a reverse direction.
4. Method according to any preceding claim, wherein, during the measuring phase, the sensor has air applied to the reference portion thereof.
5. Method according to claim 1, 2 or 3, wherein, during the measuring phase, the sensor has gas of a known composition applied to the reference portion thereof.
6. Method according to any preceding claim, wherein the sensor comprises a heat conductivity sensing cell.
7. Method according to any preceding claim, wherein the sensor or cell is located in an atmosphere contained in said chamber; including the step of circulating air within the chamber; and wherein, during the calibrating stage, air being circulated in the chamber is conducted from within the circulating stream to the reference portion of the sensor.
8. Methods of compensating for drift or setting of the zero point of a sensor substantially as hereinbefore described with reference to the accompanying drawings.
9. A device for carrying out the method according to any of the preceding claims, substantially as hereinbefore described with reference to the accompanying drawings.